National Plan for Civil Aviation Human Factors: An Initiative for Research and Application

National Aeronautics and Space Administration

Department of Defense

Federal Aviation Administration

First Edition

National Plan for Civil Aviation Human Factors: An Initiative for Research and Application

Executive Summary

Human factors related aviation incidents and accidents remain subjects of great public concern. Despite the aerospace industry's success at developing ever more sophisticated and reliable technology, the proportion of human error-related incidents and accidents remains remarkably constant. This fact, combined with projected growth rates and the requirement to increase productivity, resulted in considerable attention to human factors research and application programs over the last several years. Valuable programs in aviation human factors have been underway for many years at the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), and Department of Defense (DOD), as well as in academic and industry sectors. However, to continue to enhance this progress toward safety and productivety goals, increased coordination, funding, and long-term, high level management support in government and industry is needed. This initiative outlines a coherent national agenda containing two major elements aimed at achieving this outcome. The first element focuses on five research thrusts.

- **Human-centered automation**
- **Selection and training**
- **Human performance assessment**
- **Information management and display**
- **Bioaeronautics**

The second element focuses on opportunities for improving the application of research results to planned and ongoing programs. Too often, government, academic, and industry programs lack the mechanisms to effect the transfer of the human factors knowledge contained in research products. Implementation of the following four management actions is essential to institutionalize human factors activities in the workplace and to maximize the benefit of a national human factors program.

- **Establish and implement the policies and processes necessary to create an environment for change**
- **Develop human factors education and training programs at all levels**
- **Equip personnel and facilities with modern tools and techniques of the human factors engineering discipline**
- **Develop and maintain the infrastructure to translate and disseminate human factors products, and guide the organization's functions involving the human component**

The aviation community plays a fundamental role as both the initiator and the recipient of research and application activities. As initiator, the aviation community causes federal agencies and their contractor/academic support organizations to respond to aviation requirements through need definition, budget influence, and research support. As the recipient, the aviation community benefits by accepting and using the research and application products. This document identifies near- and long-term needs, assesses the progress of research, and provides mechanisms for implementation. The publication of this document represents one of several necessary steps to establish and maintain a coordinated national human factors program for civil aviation. Continued emphasis on research activities over the long-term as well as sustained management support for program implementation and technology transfer are needed. This initiative describes these sustaining activities which involve an iterative process for initiators, performers, and recipients. If properly implemented and adequately supported, the National Plan for Civil Aviation Human Factors will lead to significant improvements in overall system safety, efficiency, and capacity for the benefit of the ultimate customer -- the flying public.

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FOREWORD

In November 1990, the National Plan for Aviation Human Factors was published in two draft volumes under the sponsorship of the FAA in coordination with NASA, DOD, other government organizations, academia, and industry. Volume I provided a strategic view of the National Plan and summarized the detailed technical agenda contained in Volume II. The National Plan was released in draft form to facilitate coordination and expose it to the review of a widely diverse audience. Between then and now, changes in technologies, priorities, organizational structures, strategic planning and perspectives within aviation and associated organizations offer an opportunity to re-focus the community on salient issues. Additionally, opportunities for enhancing the human factors integration in the National Airspace System (NAS) will result from improving the mechanisms for coordinating research and emphasizing the management initiatives that address persistent and pressing problems. Responding to these changes and opportunities, representatives of the aviation community collaborated in reviewing the needs and requirements for human factors research and application. The following document represents a revised National Plan for Civil Aviation Human Factors in one volume that provides the necessary linkage to the detailed research plans, programs and processes employed within each participating organization. As an overarching document, this initiative prescribes the central goals, objectives, progress, and challenges for the long- and short-term future of human factors research and application.

Sincere thanks are expressed to the many members of the aviation community who, through their vigilance and dedication to aviation safety and productivity, materially contributed to the revised Plan and continue to foster greater consideration of human performance in development and operation of aviation systems.

To comment on the National Plan for Civil Aviation Human Factors: An Initiative for Research and Application, please use the enclosed FAA Memorandum form at the back of this document.

An Initiative for Research and Application

I. Human Factors in the National Airspace System:

Purpose of the Plan

To enhance aviation safety and improve efficiency of operations

The purpose of the National Plan for Civil Aviation Human Factors is to describe the human factors actions required by the aviation community to achieve and maintain the world's safest and most efficient National Airspace System (NAS). It provides a framework for the aviation community to initiate research and management activities to produce and use technical findings. Two goals are paramount--reducing error in human- system interactions, and increasing the efficiency of human-system performance. Attaining these goals requires the following four iterative activities:

Identifying operational needs and problems involving human performance

Appendix A represents a joint industry/government articulation of current and persistent operational human performance issues that cut across the aviation environment. However, identification of operational needs and human performance is a continuous process because research solves some problems while changes in technology, organizations, systems, and operations introduce new ones.

Guiding research programs in federal organizations to address operational priorities

A substantial amount of human factors research currently exists, especially in the FAA, NASA, DOD, and the international community. Coordination among programs is necessary to promote efficient use of national resources, ensure that significant gaps do not occur, prevent unnecessary overlap, and evaluate the level of effort required to achieve priority objectives. Implementing mechanisms permit participation by the aviation community in identifying and addressing operational research priorities.

Eliciting the participation of the nation's top scientists and aviation professionals in government, industry, and universities

Research is ongoing in all three types of organizations with many positive results, but greater progress can be achieved. The community needs a stronger infrastructure to facilitate the exchange of information and collaboration in planning and executing research programs.

Facilitating transfer of research results to the operational community

In addition to merely publishing results in technical journals, human factors experts must work directly with the operational community (e.g., organizational managers, airline training departments, equipment designers, and certification personnel) to implement research findings effectively. Evaluation of products prior to implementation and establishment of appropriate feedback mechanisms are also necessary to guide future research and its application.

The implementation section of this document describes specific but flexible means to accomplish these four goals. The benefactors of successful implementation are widespread across government and industry. Within government, Flight Standards and Certification personnel gain better knowledge of how aircraft flight deck and cabin design features, as well as training and operational procedures, affect human performance and safety; Aviation Security elements incorporate human performance criteria in airport systems and staffing; and Air Traffic Control and Airway Facilities acquire the information required to procure and operate efficient error-resistant systems. In addition, manufacturers gain the knowledge and information required to develop systems that operate effectively within the NAS. Operators within the NAS achieve the ability to apply more effective personnel selection and training programs. General aviation receives equipment and procedures that enhance safe operation at lower costs thereby increasing total airspace system capacity. Together, these benefits accrue to the aviation community and the flying public, substantially improving system safety and efficiency. This implementation is dynamic, influenced by and responsive to, the economic imperatives of the country; the increased awareness of, and concern for, human performance in modern systems; and, the enhanced technological capability and associated procedures (like free flight) to respond to higher expectations for both safety and efficiency.

Plan Accomplishments

- identifies operational needs from the public sector, customer requirements, and technology opportunities
- initiates enhancements to the cooperation and coordination of human factors efforts
- articulates common broad thrusts and objectives to facilitate cooperative coordination
- represents expressed views of diverse aviation community groups
- provides an agenda for near- and long-term human factors research initiatives
- provides a focus for operational implementation of research results
- commits to achieving key steps in implementation
- complies with mandates from legislative and executive authorities

Background

Recognition of the importance of human factors in the design and operation of the NAS and its components is not new. As early as 1951, under the direction of the Air Navigation Development Board, the Ohio State University Research Foundation (overseen by the National Research Council) conducted the first study calling for a major national research program in human factors for air traffic control (ATC). Several other efforts followed this study but to this date, no comprehensive, coordinated aviation human factors plan has been successfully implemented. The reasons for this failure include: 1) the noticeable absence of long-term, high level support in many Government and industry organizations; 2) inadequate funding in light of the magnitude of the challenge; 3) failure of research organizations to coordinate human factors programs effectively; and, 4) ineffective programs to transfer human factors "technology" to industry and the operational community.

In 1988, the United States Congress Office of Technology Assessment (OTA) published the results of an in-depth aviation safety investigation in a report entitled Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment. The report concluded that human factors related research was not well coordinated among government agencies and that research funding was inadequate. At the same time, the Air Transport Association of America (ATA) organized a Human Factors Task Force composed of industry and government representatives involved in research and operations that offered similar conclusions and proposed the development of a "National Plan to Enhance Aviation Safety Through Human Factors Improvements." The ATA Task Force also made recommendations regarding national research priorities. Aware of increased public concern, the U.S. Congress in November 1988, enacted new legislation, "The Aviation Safety Research Act of 1988" (Public Law 100-591). This legislation called for the FAA to augment its research efforts in human factors and to coordinate programs with those of NASA.

Responding to the congressional mandate, FAA and NASA conducted efforts to fulfill the coordination objectives set by Congress. They established a senior level coordinating committee jointly chaired by representatives of FAA, NASA, and the Department of Defense (DOD); developed Memoranda of Understanding (MOU) for collaborative research in all areas of aviation human factors; and organized Scientific Task Planning Groups (STPG) for interagency participation in the development and publication of a national aviation research agenda. Following the adoption of the ATA objectives from the operational community and FAA prioritization of its own operational and research and development (R&D) needs, the STPGs (composed of leading scientists from diverse aviation human factors disciplines and involved in research programs at FAA, NASA, DOD, Department of Energy's Los Alamos National Laboratory, the Department of Transportation's Research and Special Projects Administration/Volpe National Transportation Systems Center, and the United Kingdom's Civil Aviation Authority) developed a technical program that would address national aviation priorities over a ten-year period. The results of this multi-agency collaborative process were first published in the National Plan for Aviation Human Factors, November 1990.

Strategy for the Updated National Plan

The revised National Plan re-emphasizes human performance from a NAS perspective where the system encompasses the broadest interests of the aviation community including flight deck, aircraft cabin, air traffic control, airway facilities, aircraft maintenance, and commercial and general aviation operations, as well as the regulatory and organizational activities affecting these elements. This initiative describes the contributions of NASA, FAA, and DOD along with structured recommendations from the private sector of the aviation community. It addresses current and future research needs and required implementation activities arising from discussions within the public and private sectors of the aviation community.

This initiative expands upon the original document and responds to the many changes and experiences in the aviation community since 1990. It emphasizes the federal agency efforts and private industry aviation input necessary to develop and implement a broad-based, technically sound national civil aviation human factors program. The initiative represents commitments and views expressed by representatives of the three federal agencies (FAA, NASA, and DOD) and industry and meets the need to be customer responsive and fiscally responsible.

Changes since 1990

- Technological changes in the design, development, and deployment of aviation systems
- Increased evidence and understanding of the critical importance of the human component in safety and efficiency
- Redefined strategic objectives as well as shifting national and global economic and political priorities
- Government efforts on harmonization and coordination with Joint Aviation Administration activities
- Programmatic changes within organizations such as increased NASA emphasis on aeronautics (both subsonic and supersonic), DOT initiatives in intermodal human factors coordination, and DOD technology transfer programs
- Changes in process and policy in government and aviation related organizations
- Observations expressed by individuals and organizations responsible for the country's aviation industry
- Experience gained through the application of the National Plan since the original draft

Two strategic foci are presented:

- **A *research* focus to provide relevant human factors methods, techniques and data to meet customer needs**
- **An *application* focus to accept, implement, and integrate human factors products into engineering development and regulatory activities of the aviation community**

The following sections describe each of these essential strategic foci in greater detail.

II. RESEARCH NEEDS AND OBJECTIVES

In addition to the Congressional mandate for a coordinated research-based human factors program, the need for human factors research stems from the realization that human error has been identified as a causal factor in 60 to 80% of air carrier, commuter, and general aviation accidents and incidents. While the approximate proportion of incidents and accidents involving human performance considerations has remained the same over recent years, the perspective from which people view such error rates *has* changed in two ways--safety and productivity.

First, from the safety perspective, the constancy in the rate of detected errors attributed to humans provides little comfort in light of the anticipated growth in aviation operations. Government and industry studies show that if solutions are not found that reduce the current rates of "human error" in accidents and

Safety

incidents, increased use of aviation transportation systems in the future will result in an intolerable magnitude of loss (and cost). Furthermore, the persistent nature of human error suggests that there is no guarantee the error rate would not go up were attention to human factors less diligent. As systems become more technologically reliable, only the ardent pursuit of error-tolerant and error-preventive solutions will reduce (or even maintain) the proportion of error attributable to the human.

Also from the safety perspective, identifying the sources of error presents no simple task. Properly investigated and analyzed causal factors cannot rely solely on first order attributions to "operator error." It is now widely acknowledged that errors are largely a result of a confluence of factors (rather than one simple factor), and that these multiple components involve complex processes associated with human behavior such as cognition, organizational dynamics, individual differences, and how they interact with system design.

In addition to the importance of error frequency, the members of the aviation community recognize the potential impact of a single error in modern aviation environments (e.g., congested airways, larger aircraft, populated urban development around airports, complex flight deck and air traffic control technology). The growing consequences of error requires greater attention to the role played by operations, systems management, and support personnel in error recognition, prevention, and occurrence. The complexity of the airspace system and its environment entails a tighter coupling between the various components of the airspace system, in which even a small deficiency in one area can result in, or be linked to, a (potentially catastrophic) malfunction in another area often in an subtle manner that is likely to be recognized only in hindsight during an accident investigation.

The modern inter-dependencies of error, the tightness of aviation component coupling, and the high consequence of error require stretching human-system capabilities to enhance performance and to capitalize upon technological advances in materials, avionics, data collection, information access, and decision support systems. These technological changes, as well as an increased expectation of the human to accommodate them, create more uncertainties and require additional human performance research to help develop future systems that are error-resistant and error-tolerant.

Second, the economic imperatives for performance enhancements and the public's expectations for increased efficiency reflect the productivity perspective. In an environment where operating and support costs make up 80% of system life cycle expenditures (50% of which are directly attributable to the cost of

Productivity

people), no operational system can afford to ignore the human component. Even for those operations that depend primarily on software, the human interface requirements represent 50% of software development costs. Within an increasingly competitive and global economy, and one in which inefficiencies are increasingly more visible (e.g., wasted fuel, costly spares, equipment damage, delays, and cancellations), both public and private constituencies demand greater cost constraints as well as improvements in government's role, industry's responsiveness, and coordination between the two. These expectations of economic and operational enhancement come when concomitant resource constraints impose greater demands upon the research community to do more with less.

It is in the context of these changes that the aviation community coordinated a revised response for the national research needs (summarized in Appendix A), structure, and agenda by transforming the eight objectives articulated in earlier versions of the Plan to the five national research thrusts presented in this document. This structure and agenda for a national human factors research program are responsive to internal and external customers, technically cohesive, and thoroughly coordinated. The five overarching thrusts for human factors research projects cut across aircraft flight deck and cabin, air traffic control (ATC), airway facilities (AF) systems and services management, aircraft maintenance, aviation security, and aviation operations. The five key research thrusts transcend organizational boundaries and agency unique requirements to provide the information necessary to achieve expectations for NAS safety and productivity.

Five Thrust Areas

1. Human-Centered Automation

Human-centered automation research focuses on the role of the operator (active or passive) and the cognitive and behavioral effects of using automation to assist humans in accomplishing their assigned tasks for increased safety and efficiency. The research in this area addresses the identification and application of knowledge concerning the relative strengths and limitations of humans in an automated environment. It investigates the implications of computer-based technology to the design, evaluation and certification of controls, displays, and advanced systems.

Objectives

Automated systems designed from a technology-centered perspective tend to place the human operator in a monitoring role. The development of "human-centered" automation principles which enhance overall system performance focuses on:

- resolving issues related to the degradation of basic skills with the associated performance implications should the automation fail
- overcoming the hesitancy of human operators to take over from an automated system even when there is compelling evidence of a problem
- keeping the operator-in-the-loop and situationally aware of system performance
- designing human-machine interfaces for advanced systems
- balancing operator workload (high and low) associated with automated systems

Progress

The development of concepts and guidelines for applying human factors in the design, development, evaluation, and certification of advanced technology control and display systems for flight deck, air traffic control, and airway facilities has contributed significantly to the progress of human factors application in aviation systems. Other products of these research endeavors include:

- human factors guidelines for developing, testing, and certifying user-interface designs of various data link applications
- empirically based recommendations on a modular approach to automating ATC
- results of field evaluations conducted on automated tools to aid controllers in the safe, efficient management of arrival and departure traffic

Future Challenges

Some of the challenges to be faced in the future are determining what, when, and how much to automate; developing human interface standards for controller and maintenance workstations; integrating the conceptual models of human-system interactions into a working framework for problem identification and resolution; and, determining how much automation is enough to improve safety and efficiency under a range of operational conditions. Further research is required to:

- determine and analyze methods of automation management (such as providing fixed automation alternatives or employing adaptive automation)
- identify the workload and performance implications of applying new automation to operators' tasks
- analyze new classes of error that result from new technology (such as displays, controls, or advanced automation concepts) and new or revised operational procedures
- prescribe the proper role of the operator to avoid the human becoming a “systems monitor”
- examine methods to articulate and coordinate a “human-centered” philosophy (vs. “technology centered” in which only residual tasks may remain)
- assess the operator’s role during system malfunction and restoration
- enhance performance of less experienced operators and infrequently practiced skills
- foster situational awareness especially at critical times
- investigate how overautomation and lack of appropriate feedback to the operator create performance problems
- identify the conditions that may lead to over-reliance or under-reliance on automation

Issues in Human-Centered Automation

Workload	**1)** Too little workload in some phases of flight and parts of ATC operations to maintain adequate vigilance and awareness of system status; **2)** too much workload associated with reprogramming when flight plans or clearances change; **3)** transitioning between different levels of workload, automation-induced complacency, lack of vigilance, and boredom for flightdeck, ATC, and monitoring of system and service performance.
Operational Situation Awareness and System Mode Awareness	**1)** The ability of operators to revert to manual control when the advanced automation equipment fails; **2)** an inadequate "cognitive map," or "situational awareness" of what the system is doing; **3)** problematic recovery from automation failures; **4)** the potential for substantially increased head down time; and, **5)** difficulty and errors in managing complex modes.
Automation Dependencies and Skill Retention	**1)** The potential for controllers, pilots, and others to over-rely on computer generated solutions (for example in air traffic management and flight decisions); **2)** hesitancy of humans to take over from an automated air traffic and flight deck system; **3)** the difficulty in maintaining infrequently used basic and critical skills; **4)** capitalizing upon automation-generated alternatives and solutions; **5)** monitoring and evaluating pilot and controller skills where computer-formulated solutions disguise skill weaknesses; and, **6)** supporting diagnostic skills with the advent of systems which are more reliable and feature built-in self-diagnostics (such as those in "glass cockpit" systems and fully automated monitoring AF systems).
Interface Alternatives	**1)** Major system design issues that bridge all aviation operations include selecting and presenting information for effective human-computer interface; **2)** devising optimal human-machine interfaces for advanced ATC and AF systems and for flight deck avionics; and, **3)** devising strategies for transitioning to new automation technologies without degrading individual or contemporary system performance.

2. Selection and Training

NAS efficiency and effectiveness is enhanced through research to understand the relationship between human abilities and aviation task performance; to enhance the measures and methods for the prediction of future job/task performance; to develop a scientific basis for the design of training programs, devices, and aids; to define criteria for assessing future training requirements; and to identify new ways by which to select aviation system personnel. The recipients of research findings on selection and training are flight crews, air traffic controllers, AF systems management personnel, aircraft maintenance technicians, airport security, and others in the aviation community who contribute to safety and efficiency through staffing and training decisions.

Objectives

Interest in this area includes training for, and measurement of, effective individual and team performance; assessing the appropriate knowledge, skills, abilities and characteristics needed to excel in highly automated environments; developing guidelines for effective training materials and instructional delivery systems for individuals and teams in the complex working environments; education, training, and evaluation of countermeasures to stressors that impact on performance (such as fatigue); assessing the impact of new technology on job characteristics and requirements, and the associated consequences for selection and training.

Progress

Progress made in high-fidelity real time simulation technology resulted in significant developments in training with the use of Line-Oriented Flight Training (LOFT) and Crew Resource Management (CRM) programs to provide realistic training in flight crew coordination, judgment, and decision making in flight operations. Aviation research accounts for the initial development of:

- an automated performance measurement system for evaluating flight crew training program effectiveness
- tools and reference information for improved performance-based air traffic controller selection, training, certification, and retention
- training and performance requirements for airway facilities technicians in a satellite-based environment to support future Global Positioning System (GPS) needs
- visual and nondestructive inspection guidelines for aircraft maintenance
- intelligent tutoring systems and job aids for industry aircraft maintenance technicians and FAA Aviation Safety Inspectors
- CRM evaluation guidelines for pilots, cabin attendants, air traffic controllers, and aircraft maintenance technicians impacting system design, certification and regulation decisions, operations directives, and training procedures

Future Challenges

Due to rapid changes in technology, the economic life of hardware and software continues to decrease, requiring modification and upgrades during their economic life. Therefore, to maintain the workforce's skills, continuous training is required. The aviation industry must devise modern approaches and conduct further research in selection and training to accommodate the impact of advanced automation on the NAS and meet the high performance requirements within resource constraints. Selection and training research will provide the basis to accelerate and improve the quality for acquiring and maintaining required skills for aviation operations. Research must be pursued to:

- implement modern team training concepts for enhanced coordination
- create cost-effective new equipment training guidelines and procedures
- define the changing profile of job-related characteristics needed by applicants
- address training for mixed fleet and multi-cultured crews
- devise efficient methods and tools by which to select qualified candidates without high attrition costs
- evaluate and remediate skill decay for diagnostic and complex operational tasks
- provide integrated team training for all aviation operations
- develop training methods to promote optimum use of automation
- develop and validate advanced training delivery systems that meet future personnel staffing and training requirements

Issues in Selection and Training

New Equipment Training Strategies	**1)** Training pilots, controllers, security personnel, and systems management specialists to transition to new technologies and the associated tasks for new equipment; **2)** new training concepts for flight crews, controller teams, security staffs, and AF system management teams; **3)** measuring and training for the performance of new tasks associated with equipment predictive capabilities (vs. reactive type tasks) for pilots and air traffic controllers; **4)** methods to train personnel in the use of computer decision-aiding systems for air and ground operations; and, **5)** improved strategies for providing the required student throughput within training resource constraints on centralized training facilities, training devices, and simulation.
Selection Criteria and Methods	**1)** Evaluation of individual and aggregate impacts on personnel selection policies of changing requirements in knowledge, abilities, skills, and other characteristics for flight crew, controller, and airway facilities operations associated with planned and potential changes in the NAS; **2)** expanded selection criteria for pilots, controllers, technicians, and inspectors from general abilities to include both more complex problem-solving, diagnostic, and meta-cognitive abilities as well as the social attributes, personality traits, cultural orientation, and background biographical factors that significantly influence operational performance in a highly automated NAS; and, **3)** development of measures to evaluate these more complex individual and team-related abilities in relation to job/task performance.

3. Human Performance Assessment

Research under this thrust targets improvement in the understanding of human performance capabilities and limitations in aviation and the means to measure them. Cognitive and interpersonal skills of individuals, characteristics of teams, and organizational factors directly shape the safety and efficiency of aviation operations. This research will provide information to improve safety and productivity through better equipment design, training, and system performance.

Objectives

Objectives of this thrust are to identify the intrinsic characteristics of individuals and teams that determine how well they are able to perform aviation tasks; to characterize the impact of environmental (external and internal) and individual factors on human performance; and, to improve and standardize methods for measuring human performance.

Progress

Applying research results in this area to current technologies proved successful in providing insight and solutions to workforce performance problems. Applications have resolved concerns in the areas of shiftwork, fatigue, and work rest schedules as well as many of the effects of organizational and management culture on human performance. Research has provided effective means to use computerized, high-fidelity, real-time simulation; and valuable procedural performance modeling. Progress has also been made in enhancement of air traffic controller memory techniques and scanning patterns.

Future Challenges Techniques to improve the quality of critical decisions must involve the interaction of human performance monitoring, multiple resources in the identification of potential environmental hazards, and varying levels of risk management authority. Research is needed to understand better, measure more effectively, and address more efficiently for teams and individuals the areas of complacency, workload, situational awareness, judgment, decision-making, and individual and team performance. Further study is necessary in:

- context-based analyses of operational errors
- human aptitudes and limitations in operational terms
- learned expectations and their interactions with system design, training, procedures, and level of automation
- effective countermeasures to reduce errors and performance inefficiencies associated with social, domestic, and environmental stressors

Issues in Human Performance Assessment

Human Capabilities and Limitations	Determining the measures and impacts of: **1)**cognitive factors underlying successful performance in planning, task/workload management, communication, and leadership; **2)** the ways in which skilled individuals and teams prevent and counteract errors; **3)** ways to reduce the effects of fatigue and circadian dysrhythmia on controllers, mechanics, and flight deck and cabin crews; **4)** baseline performance characteristics of controllers so the impact of automation can be assessed; and, **5)** qualifying the relationship between age and skilled performance.
Environmental Impacts (external and internal)	**1)** Assessing the influence of "culture" on human performance including the impact of different organizational and ethnic cultures, management philosophies and structures, and procedural styles; **2)** determining methods to accommodate mixed corporate, regional, and national views of authority, communication, and discipline; **3)** addressing variations in aviation equipment design philosophies and training approaches; and, **4)** understanding population stereotypical responses in aviation operations.
Methods for Measurement	Devising effective aviation system monitoring capabilities with emphasis upon: **1)** expansion of the collection, usage, and utility of human performance data and data bases; **2)** standardization and improved awareness of critical human factors variables for improved collection, classification, and use of reliable human performance data; **3)** standardization of classification schemes for describing human factors problems in human-machine systems; **4)** better methods and parameters to assess team (versus individual) performance parameters for flight and maintenance crews, air traffic controllers, security and aviation operations personnel; **5)** improved understanding of the relationship between actual performance and digital data measurement methodologies for the flight deck to predict future air crew performance based on trend data.

4. Information Management and Display

Research conducted under this thrust seeks improved safety and performance by addressing the presentation and transfer of information among components in the NAS including controller workstations, flight deck, operational and airway facilities, and all the interfaces in between.

Objectives This thrust seeks to decrease the high rate of incidents relating to information transfer (cited in 70% of Aviation Safety Reporting System incidents) which is, perhaps, the most common and persistent problem facing the aviation system. Increased dependence upon sophisticated information transfer technologies creates a need for additional emphasis on understanding potential sources of error in this area. Objectives are to identify the most efficient and reliable ways to display and exchange information; determine what, when, and how one might best display and transfer information to system components; design the system to reduce the frequency of information transfer errors and misinterpretations; and minimize the impact when such errors do occur.

Progress Significant progress made in this technology-dependent area includes the development of prototype information systems and improved methods for display, documentation, and dissemination of aircraft maintenance and airway facilities management information. Other achievements include:

- design and evaluation of instrument approach charts and checklists, both paper and electronic
- analysis of ATC/pilot communication errors in voice and data link operations
- human factors guidelines to set policies for data link architectures and procedural links to flight management systems
- human factors guidelines for industry and government communication, data exchange, and support infrastructure
- assessment of the loss of "party line" information associated with data link implementation
- establishment of units of measure for pilot/controller voice communications
- job aids, intelligent tutoring, and electronic documentation for airway facilities maintenance technicians
- provision of routing and aviation weather products via digital links

Future Challenges The aviation community needs to conduct further research to increase the availability and quality of information exchange performance data; establish information exchange guidelines and standards for various modes and media; and, generally enhance the exchange of information between people and between people and systems.

Issues in Information Management and Display

Information Exchange Between People	**1)** Identify requirements for access to critical NAS communications for analysis purposes; **2)** determine the effects of pilot response delays in controller situation awareness and controller/pilot coordination (particularly with regard to delayed "unable" responses); **3)** set standards for flight crew response to messages; **4)** assess the changes in pilot/controller roles; **5)** enhance the communication training for pilots and controllers; **6)** identify sources, types, and consequences of error as a result of cultural differences; and, **7)** develop system design and procedural solutions for error avoidance, detection, and recovery.
Information Exchange Between People and Systems	**1)** Assess and resolve the effects of data communications on pilots/controllers situational awareness; **2)** determine the best display surfaces, types, and locations for supporting communication functions in the cockpit, at the ATC workstation, and at AF monitoring and system maintenance control centers; **3)** identify sources, types, and consequences of error, and error avoidance, detection, and recovery strategies; and, **4)** establish requirements and set standards for alerting crew, controller, and system management personnel to messages of varying importance.
Information Displays	**1)** Establish policies for operationally suitable communication protocols and procedures; **2)** set standards for display content, format, menu design, message displacement, control and interaction of functions, and sharing; **3)** assess the reliability and validity of information coding procedures; **4)** provide design guidelines for message composition, delivery, and recall; **5)** prescribe the most effective documentation and display of maintenance information; and, **6)** prototype technical information management concepts and automated demonstration hardware to address and improve the content, usability, and availability of information in flight deck, controller, aircraft maintenance, security, AF system management, and aviation operations.
Communications Processes	**1)** Devise methods of reconstructing the situational context needed to aid in the analysis of communications; **2)** analyze relationships between workload factors and errors in communication; **3)** evaluate changes in information transfer practices; **4)** set standards and procedures for negotiations and modifications to clearances; **5)** establish procedures for message prioritization and response facilitation; **6)** set standards for allocation of functions and responsibilities between pilots, controllers, and automated systems; **7)** provide guidelines on the distribution of data to, and integration with, other cockpit systems; **8)** prescribe communication policies related to flight phases and airspace, such as use in terminal area and at low altitudes; and, **9)** determine the impact of data communications on crew and controller voice communications proficiency.

5. Bioaeronautics

The bioengineering, biomedicine, and biochemistry associated with performance and safety.

Objectives This thrust addresses enhancement of personal performance and safety by maximizing crew and passenger health and physiological integrity.

Progress Positive results have enhanced performance of rescue and firefighting operations, passenger safety, and development of products and information on the effects of drugs, alcohol, and combustion components on aircraft occupant performance. Other areas of progress include:

- quantitative biochemical and toxicological criteria for certification
- functional passenger and crew breathing equipment
- flotation device design
- airman vision, cardiovascular, and neurological certification guidelines

Future Challenges Research supporting this thrust will address personal safety equipment and procedure designs that do not impede performance; anthropometric and demographic descriptions of aircraft occupants; and improved cabin egress methods and procedures as well as enhanced rescue and firefighting techniques. Additional research will be conducted in:

- crew and passenger interactions in cabin environments of larger aircraft at higher altitudes and greater speeds and distances
- performance impacts of new medications and other chemicals
- medical information and equipment for improvement of personal well-being and in-flight medical care
- minimizing the effects of illness and associated therapy on performance in aviation settings
- laser safety and performance impacts

Research Summary

The National Plan outlines the human factors core technology research agenda sponsored and managed by FAA, NASA, and DOD which is fully articulated in each organization's research planning documents and summarized in Appendices B1-B3 in this document. Specific research projects and objectives are derived from customer requirements and technology opportunities which serve to amplify the growing need for greater understanding of team and individual capabilities and limitations, and the relationship between humans and their working environment. Modifying each organization's detailed research plans involves continued collaboration among the sponsoring, managing, and performing organizations to specify research priorities, final technical approaches, organizational management strategies, anticipated operational impacts, milestones, deliverables, and resources required.

III. ORGANIZATIONAL IMPERATIVES FOR APPLYING RESEARCH RESULTS

Numerous human factors programs exemplify high standards in many critical areas of acquiring and applying human performance information. Yet, typically, even some of the best human factors programs fail during the application phase. A large disparity still exists between the state of the art and the state of the practice in aviation human factors. System development, design, and procedures decisions continue to be made on the basis of instinct and local conventions and traditions. Analysis and studies of the human factors engineering discipline show that the underlying reason for this results from the failure of these programs to incorporate one or many of the critical elements necessary for proper execution. Much of the leadership in the area of human factors applications during the past ten years has been attributed to human factors integration programs within the Department of Defense. The most notable of such programs is the U.S. Army's MANpower and PeRsonnel INTegration (MANPRINT) program which implements DOD's Human Systems Integration (HSI) program and contributed to the construction of an environment for enhanced integration of human performance considerations with system acquisition programs. Based on exploration by various working groups as well as findings from engineering research, analyses, and studies conducted by government, industry and academia; successful programs have advocated a multi-disciplinary approach to defining and optimizing the user/system interface in which the concept of design excellence is broadened to include the human operator, maintainer, and support personnel. These approaches apply equally (when properly tailored) to system development and procurement programs involving major or minor acquisitions of hardware and software systems, acquisition of non-developmental and commercial-off-the-shelf (COTS) systems, product improvements, change proposals, and the development of procedural guidelines and regulatory requirements under which systems operate. Four notable management actions are common to all exemplary approaches to systems integration.

1. Establish and implement the policies and processes necessary to create an environment for change

Within the scope of this action, procurement and regulatory policy, organizational management principles, and organizational project or product team operating practices affecting human factors are comprehensively prescribed, conditionally tailored, and diligently executed.

Objectives

Achieving this management action requires two elements. First, organizational functions must respond to clearly stated policy that provides the visibility and top-down sponsorship for human factors efforts. Bottom-up implementation is necessary always, but provides insufficient momentum to carry human performance issues to the decision makers at times of constrained budget and schedules. Policy and process requirements include those that will designate and delineate responsibilities to competent authorities, establish an organizationally recognized champion for human performance causes, offer definitive statements of support, fully describe the intent and content of human factors requirements for developing programs, provide the organization a human-centered focus, and establish controls necessary to support, coordinate and execute human factors efforts in the organization's functions.

Second, the aviation community must establish a systems approach to the application of human factors. Doing so entails establishing systematic, disciplined procedures for application to acquisition programs, regulatory (standards and certification) functions, and internal operations. The community must also consistently apply explicit consideration of the human component which entails continuity of expert effort in an iterative (both early and continuous) approach. The scope of the application must be comprehensive, addressing all aspects of human performance, staffing, training, safety and health, as well as incorporating all phases of the program (including needs analysis, requirements determination, trade-off analyses, cost/benefit analyses, life-cycle costing, source selection processes, post-contract award program activities, engineering design reviews, program management reviews, and test and evaluation). Human factors must be an integral part of all development and integration efforts, and be explicitly considered in all analyses and decisions. Organizational elements as well as companies competing for contracts must be required to formally satisfy human performance process requirements, which will result in increased human factors expertise applied to product or project design and development, as well as integration of this approach into the corporate culture. Thus, it is required to establish a view of the human as an inherent part of the system and institutionalize this user-centered approach (vs. a technology-oriented approach) within all organizational functions and processes. Success depends upon human factors being a proactive (not reactive) force for the improvement of total system performance.

Progress

In addition to the many accomplishments achieved within DOD's human-system interface programs, in 1993, the FAA adopted Order 9550.8 (formally establishing policy and responsibility for incorporating and coordinating human factors considerations into all NAS programs and activities) and, in early 1995, reorganized human factors research program management. In a related development, the 1994 organization of the NASA-Ames Flight Management and Human Factors Division preserved a national resource for human factors, enabling them to continue to serve the needs of the aviation community in research and application. While there is evidence of recent progress, the aviation community is addressing these objectives too slowly to fulfill visionary expectations.

Future Challenges

The situation continually facing many elements within the FAA, NASA, and DOD is not unlike that others face in attempting "to do more with less" or to systematize a human-centered approach. The developers of successful programs attribute their human factors accomplishments directly to the aggressive and highly visible support of senior management officials. The initiative and leadership demonstrated by the organization's managers is a major factor in the acceptance of the program throughout the workforce. Once the management support is established from the top, the details of a systematic process (for small and incremental projects as well as large ones) must be developed and applied to all functions. In order to derive the full benefit of a human-centered approach, senior management must support the disciplined adherence to human factors engineering policy and processes. This requirement would enforce the consideration of human performance issues at every major decision and event, and establish a formal process for monitoring the institutionalization of human factors considerations.

2. Develop human factors education and training programs at all levels

The scope of this management action involves those developmental activities necessary to attain and maintain a workforce competent in conducting and integrating human factors activities in organizational functions.

Objectives

This action seeks to provide the training and education necessary to achieve a common awareness and understanding of human factors at all levels of the organization as well as develop the specialized expertise necessary to apply human factors to unique organizational functions. Attaining this objective entails establishing evaluation and developmental programs to identify and meet the demands of the organization as they relate to system technology changes, new research results, revised organizational missions, and the half-life of technical knowledge. Officials who are aware of the long-term human factors needs and current deficiencies must lead the evaluation and development programs. They must employ human factors expertise in deciding who needs training, what kinds of training, how much, how to accomplish training, what frequency, what degrees of expertise are necessary, what value-added sources are available, and the like.

Progress

Numerous human factors training programs emerged from various sectors within the applications communities to fill the void in technical human performance expertise. With very few exceptions, training programs generally fail to meet the needs of the organization because they do not adequately incorporate the following characteristics:

- Treat the subject in an applied manner (i.e., integrated in the functional application)
- Address the diverse elements in human considerations with an integrated approach (e.g., integrating the considerations of staffing with those of training, or those of safety with those of ergonomics)
- Identify and address fully the required target audience
- Entrust the responsibility to individuals expert in the specific subject matter and able to assess the quality of training and development programs
- Emphasize the relationships between human factors components and those of other engineering efforts (e.g., between performance and configuration management, between training and testing)

Future Challenges

Future requirements for personnel training and development present the most challenging task ever encountered in the human factors workplace as well as in other areas of technical expertise. Increased personnel turnover, organizational turbulence, sky-rocketing costs in learning, shorter education half-life, revolutionary technology changes, accentuated value of skilled work, increasing cost of errors, greater organizational dependence upon expert intellectual capital, and severely constrained budgets all create an environment in which the training and development of the workforce plays a critical role in meeting organizational goals. Yet, new training techniques and sophisticated job aiding provide excellent opportunities to meet these challenges. In the future the community must: 1) accurately determine skill requirements and 2) develop them in a cost-effective manner. To do so entails assessing how well the current expertise will satisfy future needs, evaluating how productively the knowledge available is being used to bridge the gaps between the islands of knowledge among various disciplines and functions, and quantitatively and qualitatively measuring the value of individual and organizational wisdom, experience, and background. The future path for training and development efforts is to view human capital as a source of innovation.

Enhancing Education and Training

- ♦ Develop mechanisms to exploit the organization's intellectual human factors assets (such as information and expert systems that capture resident expertise and experience)
- ♦ Establish enhanced channels for communication of human factors knowledge and incentives to use them
- ♦ Exploit opportunities to leverage the intellectual capital within and outside the organization
- ♦ Construct gauges to determine if the trends in the organization's human factors resources are going in the right direction
- ♦ Devise ways to put new human factors ideas to work within the organization (thereby increasing the productivity and the utility of existing alerts and abilities)
- ♦ Produce data that demonstrates the value of applying human factors expertise

3. Equip personnel and facilities with modern tools and techniques of the human factors engineering discipline

The scope of this action includes acquiring the technical facilities, tools, equipment, techniques, methods, standards, measures, data, handbooks and guides needed to properly support the application of human factors information to regulatory and acquisition functions.

Objectives

The objectives of this management initiative are to enhance the capabilities and productivity of the organization's workforce by placing within their hands the proper instruments of the human factors discipline. It is to be a workforce multiplier, increasing the speed, accuracy, and value of human factors efforts. It involves providing the necessary tools and support to facilitate:

- Quantification of human variables affecting performance

- Standardization and consistency in application
- Reduction of cost associated with development work in human factors applications
- Promotion of early and systematic accommodation of human considerations
- Incorporation of human performance and usability as inherent parts of system requirements and test and certification plans
- Translation of human performance issues into the decision maker's language
- Focusing on performance-based user acceptance, usability, and operational suitability

Progress

Much progress has been made in the development of methods and techniques for applying human factors in keeping with technological changes. The use or application of these methods and techniques, however, is the key issue for consideration. A recent DOD study surveyed more than 500 tools and techniques that assist in the practice of human factors engineering. The tools and techniques range widely in scope, complexity, application, cost, utility, availability, and ease of use. For most applications within the aviation community, the issue concerning human performance methods is not about the development of new tools and techniques, but about how to place the information and tools that already exist into the hands of the people who need and can use them.

Methods & Techniques for Applying Human Factors

- ♦ State-of-the-art, human-in-the-loop system simulation modeling
- ♦ Statistical and mathematical models that analyze algorithmic descriptions of systems
- ♦ Comparability and task-based methods that decompose systems into component subsystems and subfunctions
- ♦ Guides that describe engineering and human performance parameters in varying detail

In a related development, one valuable tool emerging to support the human factors community is the National Plan Relational Data Base. In cooperation with FAA and NASA, the DOD Manpower and Training Research Information System (MATRIS) Office, a division of the Defense Technical Information Center (DTIC), established a human factors front end to the vast data base of research currently supported by the DOD. By adding abstracted information about NASA and FAA research addressing National Plan priorities to the already existing DOD research data base, the aviation community can access information about what research is being done and by whom. As this data base matures, it will bring together large bodies of disparate information about work in progress at FAA, NASA and DOD, as well as national and international human factors research issues and planned research projects. The development of this data base allows users from different backgrounds to access information that is relevant to their needs, and it enables prompt updating of detailed elements of the research agenda as human factors priorities change and results become available. Users are able to retrieve information on current and needed research in aviation human factors, categorized by associated thrusts, sponsors, and human factors key words. Names of responsible and performing organizations are provided, so interested persons are able to access information about findings and planned follow-up research. Perhaps the most valuable contribution of the National Plan Relational Data Base is the improved opportunity for researchers and program managers across the aviation community to share information about relevant research and findings.

Future Challenges There is still a need for efforts that focus on the development of standards and facilities that support state-of-the-art human factors research and engineering activities. The challenge for the aviation human factors community is to interject critical human performance information into the product/project decision process sufficiently early and adequately quantified to enable a confident assessment of the risk and sensitivity to human considerations. The needs of the future will require the availability of tools and techniques to accomplish the following:

- Provide baseline quantification of human performance variables
- Assess and reduce the human resource component of life cycle cost (e.g., staffing and training)
- Enhance systematic early warnings of human error probabilities and consequences
- Identify performance standards for industry
- Facilitate consistency of effort and capture lessons learned
- Increase early design "trade-offs" and sensitivity to human factors considerations
- Use human factors tools to push technology (i.e., be a technology driver vs. a constraint)

4. Develop and maintain the infrastructure to translate and disseminate human factors products, and guide the organization's functions involving the human component

Both the people and organizational structures needed to support the research and application of human factors principles and techniques exist within the scope of this action. In addition to the number of human factors experts needed, equally important are the background, experience, and organizational setting for this workforce.

Objectives To develop a competent human factors workforce depends on the expertise available for application of human factors to projects and the consistency with which human factors professionals are involved in work being done within an organization. Factors for consideration in the development of such a workforce include:

- the length, breadth, and type of individual and collective experience
- the engineering, social science, and behavioral science disciplines represented
- the continuity of human factors technical expertise to projects during critical phases of development and decision making

Considerations for Developing the Workforce

♦ Organizational placement

♦ Collocation for critical mass and intra- and inter-disciplinary coordination

♦ Assignment of responsibilities and authorities for committing human factors resources and for determining how to utilize and supervise critical skills

♦ Description of how and by whom human factors personnel requirements are determined and met

Progress

Few would dispute that strong leadership and the enthusiastic support of senior management are necessary to maintain a competent human factors component within an organization. In many organizational settings, people do not sufficiently understand or support the human factors discipline, despite public pronouncement of its critical importance. There are only rare evidences of organizations that have acquired, sustained, and effectively utilized technically superior and organizationally integrated human performance expertise for lengthy periods. The organizations achieving that status implement management initiatives that include:

- Redirection of resources to meet human factors requirements
- Establishment of high levels of visibility and responsibility for user-centered concepts
- Exploitation of expert knowledge in the use of human factors tools, data bases, techniques (i.e., knowing what works, what doesn't and when) to conserve critical resources
- Nurturing the growth of human factors knowledge in application areas (e.g., regulation, certification, operations, acquisition)

Future Challenges

To integrate human performance considerations into the development of products, those responsible for the outcome of the effort must have easily accessible, well-qualified human factors expertise to provide the necessary data and information on human capabilities and limitations in a usable form. Development of the human factors infrastructure necessary to achieve stated organizational goals requires:

- Recognition of human factors as an essential core discipline in organizational functions
- Leverage of supplemental support (contracted or borrowed) with sufficient resident human factors expertise within a well coordinated, centrally guided program
- Use of human factors experts as the agency's "smart buyer" for human-oriented research and applications work
- Centralized control of research and application human factors resources to achieve crucial coordination and critical mass requirements (at least until fully institutionalized processes are attained)
- Direct coordination and contact of human factors personnel with operational communities

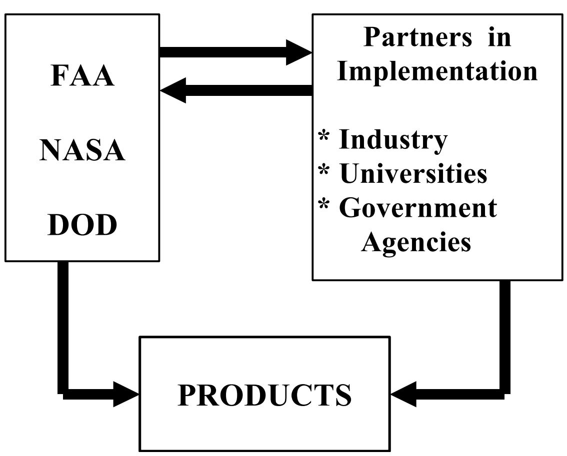
- Capitalizing upon the synergy created by the interdependence of human factors domains (i.e., training, human engineering, personnel staffing, health and safety)

Application Summary

Whether or not the new hardware, software, procedures, and training are effectively transferred to the aviation community will depend upon the degree of success in resolving human factors problems in aviation equipment, procedures, and systems. This means that human factors principles must be applied at the earliest stages of programs for new aircraft, air traffic control, airway facilities, security, and aviation operations technology and continue through full implementation. Selection and training of the right people to operate within the system is crucial, and they must have modern tools and techniques capable of identifying and rectifying human performance problems. For this to occur, an organizational commitment to a decision-making process must be in place that formally considers the human factors implications of every facet of the aviation system. This formal process must have the support of the highest levels of management in the aviation community. Moreover, it must become an integral and institutionalized element in the "culture" of the organization.

IV. IMPLEMENTATION STRATEGY

Establishing and maintaining a national planning process is necessary to resolve many of the persistent concerns in human factors research and application. This process entails maintaining the National Plan for Civil Aviation Human Factors as a vehicle for describing the actions required to address human factors; exercising a disciplined collaboration of human factors efforts that ensures comprehensive interagency coordination at all levels; and, executing the broad long-term programs delineated within this document as well as organizational plans summarized by example products in Appendices B1-B3.



This initiative and its predecessor documents repeatedly list interagency coordination and cooperation as pivotal to the success of any national plan for human factors. Participants in the national planning process cite the lack of senior level support and ineffective coordination among research organizations as a significant impediment to national human factors planning and execution efforts. To help orchestrate support and coordinate human factors requirements and time frames for program implementation, this initiative structures individual organizational programs and projects into the five agreed-upon research thrusts. To achieve mutual requirements identification, research project comparison, joint program planning, and cooperative product transition, this initiative commits to enhancing current coordination mechanisms (such as coordinating and advisory committees, working groups, and cooperative research agreements) and to developing a formalized process beginning in fiscal year 1995, under the auspices of a FAA/NASA/DOD human factors advisory group, whereby: 1) users/customers/sponsors express and define needs and requirements to each other and to research providers across agencies; 2) researchers describe programs and products that either address specific requirements or are exploratory and developmental; and, 3) researchers and customers work together to develop investment strategies and evaluate progress and coordinate new product applications. This process shall include:

- Annual identification/validation of technological and operational deficiencies and opportunities for inputs to human factors research needs
- Structured monitoring, assessment, and review of research progress and products
- Communication of major findings and results of research among developing agencies and potential customers
- Coordinated planning and monitoring by federal agencies
- Establishment of specific technology transfer steps for major products and research domains
- Verification and validation of products by the customer community with feedback to the federal agencies
- Public coordination, documentation, and dissemination of plans and products

Productivity Multipliers

- ♦ Diverse coordinating groups among government, industry, and academia for technical inputs and technology transfer
- ♦ Lessons learned, operational human performance and accident/incident data
- ♦ Jointly developed projects and collaborative research plans
- ♦ Common standards and specifications
- ♦ International coordination in research and applications

V. SUMMARY/CONCLUSION

This initiative provides a framework for the development and implementation of a coherent, coordinated national aviation human factors effort that meets the short- and long-term operational requirements for "core" and applied human factors technologies and information. It defines the environment for transferring that information to the organizations, missions, functions and projects of our national aviation community (including government, industry, and academia). It is important to recognize that the publication of this initiative represents just one of the necessary steps toward achieving the vision for a national human factors program. Implementation plans at every organizational level are also required to delineate responsibilities, establish needs and priorities, monitor technical programs, assess progress, and budget and allocate resources to support unique and common objectives. The National Plan, if properly implemented and adequately supported, provides the structure for institutionalizing the consideration of human performance issues and reducing many of the operationally significant human performance challenges facing the nation's aviation system.

The thrust objectives and required actions espoused by this initiative represent the most operationally significant issues for both the long and the short run. It seeks to maintain a balance between short- and long-range research and application needs -- attempting to address today's problems where possible while identifying long-term strategies to enhance the aviation system of the future. In order to apply human factors knowledge to the design of a NAS component to be introduced 5 to 10 years in the future it must be available today. One may also express this observation as part of a general industry and operational community frustration that research never solves problems fast enough. However, a corollary of this assertion is that a more serious investment in human factors research 5-10 years ago would have placed today's designers, developers, and regulators in a better position to make contemporary decisions. Thus, there is an important role for long-term as well as short-term efforts as a "capital investment" in tomorrow's systems and procedures. Success will depend upon the extent to which senior management creates the visibility, funding, training, and staffing necessary to fulfill human factors research and application objectives.

Appendix A: Industry/Government Task Force Research Requirements and Priorities

Overview

This appendix summarizes the information contained in the National Plan to Enhance Aviation Safety Through Human Factors Improvements prepared for the Air Transport Association/Industry Human Factors Task Force. This summary conveys the general framework established in the ATA plan for organizing high priority human factors requirements. These requirements are of great importance to the aviation industry because most aircraft accidents are caused, wholly or in part, by human error. The ATA document is organized into six parts. The philosophy statement describes the purpose of the Plan summary. The problem statement describes the need for a strong human factors program. The driving factors section identifies the factors that drive the need for ongoing human factors research. The requirements areas and domains section contains ten general categories of human factors efforts that must be pursued within each aviation domain. The needs section describes the national commitment, administrative structure, and resources required to effectively meet aviation human factors needs.

Philosophy Statement

Through the process of developing the revised National Plan for Civil Aviation Human Factors, both government and industry leaders agree on the following:

1. In order for the problems of human performance to be properly addressed, the discipline of human factors must be recognized and supported as a core technology.

2. This recognition and support is necessary from the highest levels of management in both government and industry.

3. Funding and organizational structures need to be put in place in order to demonstrate commitments and establish the necessary foundation and management mechanism required to maintain this program.

4. Once in place, these structures and funding must receive continuous and energetic commitment from management in order to remain effective.

Problem Statement

New technology using increasing automation has brought the promise of more efficient, cost-effective, and safer human-operated/machine-assisted systems. But recent experience with current systems has introduced concerns about the ability to design and manage highly automated systems without compromising safety, while keeping cost at an acceptable level. Much of the concern stems from the fact that despite the aerospace industry's success at developing ever-more sophisticated and reliable technology, the percentage of human error-related incidents and accidents has remained high. The economic impact of poor design, in terms of redesign, retrofitting, and unplanned training costs, has been significant, and future costs related to manpower and training are expected to increase as the demographics of the future workforce change dramatically. Despite the continued need for comprehensive human factors research and applications, support for human performance initiatives has waned in recent years.

Driving Factors

Many human errors that lead to accidents can be attributed to unforeseen effects of new technologies, new operational procedures, and changing organizations. Aviation exists in an extremely complex and dynamic environment, and many factors can affect safety. As these factors change, the consequences of these changes on pilots, cabin crews, air traffic controllers, maintenance personnel, and airline operations personnel must be understood and dealt with before they cause accidents.

Technology New aircraft and air traffic control systems are introducing higher levels of automation and complexity. The impacts of these changes on operator performance must be anticipated during system development, and systems must include error-tolerant and error-resistant designs to enhance performance and minimize the likelihood and severity of human factors errors.

Air Traffic Management Environment The future air traffic management environment will fundamentally change the ways pilots and air traffic controllers operate within the system. Salient changes include data link communications and terminal area productivity technologies that automate traffic flow into the terminal environment.

NAS Infrastructure The infrastructure which produces the National Airspace System services utilized by air traffic controllers and the flying public is becoming much more complex and dependent on each of the systems within it. The impact of these highly complex massive automated systems must be determined to reduce chances and consequences of error and to increase productivity.

Demographics The future pilot population will likely be different from the current population. Fewer pilots trained by the military are likely to be available, and airlines may be required to rely more on “ab initio” training. In addition, changing skill levels and workforce demographics may affect the selection and training of all members of the aviation team: pilots, controllers, cabin personnel, maintenance personnel, and airlines operations personnel. The nature and effects of these changes must be anticipated in order to develop the right standards and regulations for the future.

Organizations The workplace itself is becoming much more dynamic, with old organizations dying, new ones being born, and others changing rapidly. Individual workers may have to move quickly from job to job, and the traditional promises of organizational security may no longer be available. These changes pose great challenges to ensuring the safety and stability of the overall aviation system while accommodating the changing needs of organizations and individuals.

Cultural Just as the domestic workplace is becoming more dynamic, organizations are also becoming increasingly international. Aviation standards and practices that are incompatible with cultural expectations will lead to errors and unsafe practices.

Economic The aviation industry has been among the industries hardest hit in the latest economic downturn. Several major carriers have ceased operating and others are in or are emerging from bankruptcy. The sensitivity of the aviation industry to economic cycles makes the importance of human performance and optimal allocation of human resources even more critical.

Requirement Areas and Domains

This section contains ten general requirement areas within the aviation domains. Priorities (will be) determined by surveying representatives of each of these domain areas. The Requirement Areas establish a permanent general framework for more specific research needs which will be released each year to determine funding priorities. In the following, these general requirement areas are listed along with specific research needs closely aligned to the research agenda contained in this current version of the FAA/NASA/DOD National Plan for Civil Aviation Human Factors.

Aviation Domains

- Air Traffic Control (ATC)
- Flight Crew (including pilots and cabin crew)
- Flight Deck
- Airline Operations Centers (AOC)
- Maintenance
- Airway Facilities Management

Requirement Area	Specific Research Need
1. Determine how automation should be used and how it should not be used.	Develop a "human-centered automation" philosophy for system design.
2. Balance benefits of automation with the need for human authority and responsibility.	Apply a "human-centered automation" philosophy to systems.
3. Determine what information and feedback operators need to stay aware, in control, and able to intervene into automated processes.	Ensure that human operators develop and maintain the skills needed to intervene. Apply a "human-centered automation" philosophy to displays and controls.

Requirement Area	Specific Research Need

4. Determine the best methods for selecting, training, and evaluating operators and teams in the context of advanced systems and the changing environment.	Determine the changing requirements on personnel selection and training imposed by changes in operator role from controller to monitor, and by new technologies. Determine selection and training requirements to ensure that operators work effectively as part of a team. Determine the best methods to monitor operator and system performance during line operations.
5. Determine what policies and procedures will ensure appropriate use of automation and effective human performance and team coordination.	Determine the most affordable methods of information transfer in the future air traffic control, management, and service environment.
6. Determine what formats and interfaces will best support operator and team performance.	Apply human-centered principles to display and control design. Ensure that technical documentation standards and formats are developed to minimize errors.
7. Ensure that the operators of various interacting systems maintain coordination with each other to maintain and enhance safety and efficiency.	Determine the best methods of information transfer in the future air traffic control environment. Determine the best methods to ensure coordination between controller teams.
8. Determine the necessary procedures to ensure that human factors information is applied to acquisition, certification, regulatory, and operational activities.	Apply systematic methods to ensure that human factors considerations are treated at all stages of the system development process.
9. Determine how physiological factors, psychological, and cultural factors such as fatigue and duty cycles, affect operator performance, and develop appropriate standards to ensure safety and efficiency.	Create and test education and training modules on strategies for alertness management in flight operations. Determine the effects of circadian dysrhythmia on operator performance and develop useful countermeasures. Define the interaction of disease, injury, and various therapies on the ability to perform extended aviation operations.

Requirement Area	**Specific Research Need**
10. Determine the best methods to ensure passenger and crew safety and survivability.	

Determine the best standards for cabin configuration and materials to enhance survivability.

Determine the best methods to ensure proper coordination between flight deck and cabin crews in abnormal situations.

Needs

Initial efforts by industry and government to address Human Factors as a core technology and develop and implement the (1990) National Plan for Aviation Human Factors were quite successful. However, recent changes suggest that the recognition and momentum gained may indeed be completely lost if corrective action is not taken. Specifically, budget reductions for basic human factors research which are disproportionally larger than cuts implemented in other basic R,E&D and in operationally related programs must be reversed. Furthermore, top level commitments to human factors as a core technology must be reestablished.

The following steps need to be taken:

1. Renew our national commitment to improve aviation safety through human factors improvements and do so at all levels of government, particularly the leadership of the agencies and organizations which are responsible for and/or capable of directly supporting safety within the National Airspace System (NAS). Specifically, the Department of Transportation and the Federal Aviation Administration, the National Aeronautics and Space Administration, and the Department of Defense need to restate their commitment to this goal individually and cooperatively.

2. Provide funding sufficient to implement the National Plan for Civil Aviation Human Factors.

3. Establish, and/or maintain, core human factors research resources, facilities and technical expertise sufficient to address and respond to the high priority needs of industry. Many of these needs have already been identified and they will continue to be updated during the upcoming months and years as the industry moves to widespread use of satellites and digital technology to support the global air traffic management system.

Appendix B1: DOD Implementation Plan

The Department of Defense (DOD) completed and published a comprehensive post-Cold War Science and Technology Strategy and Plan in September 1994. Its goal is to position the science and technology investment to best support the wider range of missions faced by the military while simultaneously dealing with reduced budgets. Additionally, it directs technology development not only to improve system performance, but specifically toward reduced cost and life-time affordability. The science and technology program is formulated to satisfy national security requirements. Much of the technology is, of course, dual use in nature; that is, the technology has both military and commercial applications. In such areas the Department of Defense efforts are designed to capitalize on dual use aspects, both as a provider and a recipient. The plan is organized into nineteen major technology areas that describe the total Department of Defense Science and Technology effort. It is a milestone in that it represents the first top-level compilation of science and technology goals, challenges, payoffs, funding allocations, and timeframes for product deliveries. The plans will be periodically reviewed and updated to ensure that science and technology investment is properly executed.

Science and Technology for the human receive great attention in the Department of Defense Plan. Four of the nineteen technology areas are specifically devoted to human issues: Biomedical; Clothing, Textiles, and Food; Manpower, Personnel, and Training; and Human Systems Interface. Programs in Human Systems Interface have the most dual use application to Civilian Aviation Human Factors, as do some efforts in Manpower, Personnel, and Training. The Human Systems Interface area for the first time pulls together all programs aimed at boosting systems performance and affordability by developing and transitioning technology to ensure superior human systems operability, supportability, and survivability. Its aim is to fully leverage and extend the capabilities of operators and support personnel to ensure that fielded systems will exploit the fullest potential of the whole team, irrespective of gender, mission, or environment. Complex technologies are not only found in military systems of course, but are pervasive from the factory floor to the family living room. Linking humans effectively with these technologies is key to economic competitiveness. The technology products included in this National Plan for Civil Aviation Human Factors were directly extracted from the documented Department of Defense plans in Human System Interface and Manpower, Personnel, and Training.

DOD SAMPLE PRODUCTS AND MILESTONES - FY 95-02+

Sub-Area	FY 95-97	FY 97-02	FY 02+
Human-Centered Automation	Methods to Enhance Decision-Making Under Stress Automated Real-Time Mission Planning and Vehicle Management	Demonstrate Real-Time Electronic Associate Aiding Technology for Distributed Operations Verified Crew-Centered Cockpit Design System	Adaptive, Intent-Based Aiding Demo Biocybernetic Interface Distributed Interactive Virtual Design System for Crew Systems
Selection and Training	Methods to Capture Instructor Pilot Skills for Jobs Tests for Situational Awareness Skills Prototype Virtual Reality-Based Trainer	Next Generation Aptitude Tests Intelligent Tutor Authoring System Flexible, Reconfigurable VR-Based Trainers	Advanced Predictors of Job Success Fully Networked Synthetic Training VR-Based Intelligent Tutor
Human Performance Assessment	Crew Station Flight Test System Human Mental Workload Metric	Electronic Data Base of Human Factors Information Decision-Making and Situational Awareness Metrics	Real Time Measures of Human Performance
Information Management and Display	Panoramic Cockpit Display Demo 3-D Audio Flight Demo Lightweight Night Vision System	Lightweight Helmet Displays 300 Sq. In. Flyable Flat Panel Display	Real-Time On Board Data Fusion VR-Based Cockpit
Bioaeronautics	Accommodation Criteria for Women, Minorities Human CAD Models for Equipment Design	CAD Models of Impact Injury Full Body Imaging Survey and Data Base	Fully Integrated Crew Protection Systems Hi-Fidelity 3-D Human Models for Equipment Design

Appendix B2: NASA Implementation Plan

The strategic vision of the Office of Aeronautics encompasses the identification, development, verification, transfer and applications of high-payoff aeronautics technology to serve the United States. It seeks to promote economic growth through superior, safe and environmentally compatible products for the aviation community so that this community has a world leadership capability through technology. This community includes not only industry, but also the Federal Aviation Administration, the Department of Defense, other government agencies and academia.

Human Factors methods, techniques and findings emanate from the accomplishment of several aeronautics strategic goals. Of particular importance to the National Plan are three goals.

- To develop high-payoff technologies for a new generation of environmentally compatible, economic subsonic aircraft, and a safe, highly productive global air transportation system.
- To develop the technology base for an economically viable and environmentally compatible high-speed civil transport (i.e., speed: Mach 2.4, 5500 mile range, 300 passengers, 2-person crew).
- To develop advanced concepts, understanding of physical phenomena, and theoretical, experimental, and computational tools--including High Performance Computing and Communications technologies--for advanced aerospace systems.

The first two goals are embodied in two major application domains: 1) the Advanced Subsonic Transport (AST) Program, and 2) the High Speed Research (HSR) Program. The third goal is addressed by the Critical Technologies (CT) Program. Each of these goals is embodied in major research programs. Each program, in turn, is documented in the specific program plans, called the AST Program Plan, the HSR Program Plan, and the Base Research and Technology Program Plan. Within each, the program vision, objectives, milestones, deliverables and budget are stated. Human Factors research projects are described along with major milestones and products.

Advanced Subsonic Transport: AST focuses human factors research on three areas:

1. Terminal Area Operations, especially enhanced human factors capabilities in reduced visual conditions on the ground and in terminal areas for in-flight modes, for advanced communications via data link methods, and for human-centered automation via enhanced aids. Major milestones and products are:

    - Complete field evaluation of concepts, technology and procedures for extended terminal area air traffic controller automation aids - FY 96
    - Provide validated guidelines for robust Air Traffic Management operations with varying levels of automation and varying combinations of data link and voice air-ground communications - FY 97

2. Rotorcraft Operations, especially low level flight management and displays under poor visibility conditions. Civilian applications of joint NASA-Army programs also are included, such as aids to emergency medical and public safety operations. Major milestones and products are:

- Complete simulation of MIDAS (a rapid prototyping design, test and evaluation tool) to analyze and evaluate proposed cockpit designs and crew procedures for civil tiltrotor terminal area operations - FY 96
- Demonstrate operational procedures and guidance/displays for safe low-altitude, terminal area operations in civil rotorcraft - FY 99

3. General Aviation human factors emphasizes increased safety and decreased cost of single-pilot light transportation aircraft by providing integrated cockpit systems, including simplified displays, controls and operations. Major milestones and products are:

    - Flight evaluation of integrated controls and displays - FY 97
    - Validation of guidelines and standards in flight for certification of pilots and integrated controls and displays for reduced time and cost for pilot training - FY 00

High Speed Research: The HSR Program addresses human factors technology for an evolutionary flight deck. Specific attention is given to development of enhanced and synthetic displays that allow the crew to taxi, take-off, cruise and land without direct forward vision under Category IIIB equivalent operations. Major milestones and products are:

- Demonstrate a real-time system landing an aircraft without forward visual aiding through enhanced/synthetic displays - FY 98
- Demonstrate under operational conditions an enhanced/synthetic vision system for aircraft operations - FY 99

Critical Technologies: The CT program of research in human factors focuses on the mid (i.e., next 5 years) to long range (i.e., beyond 5 years). Five related areas of research are supported: 1) Development of models and data bases of human cognitive and sensory processes and the psychophysical limits of human performance; 2) Development of procedures, countermeasures to human error and processes to enhance human performance; 3) Determination of aeronautical applications of advanced human-system interfaces, including virtual reality; 4) Development of human engineering dual use applications of the technology within aeronautics and beyond, such as education and health care. Major milestones and products are:

- Demonstrate a real-time system for measuring the level of pilot awareness based on psychophysical data - FY 96
- Demonstrate operational alertness management expert system that builds upon laboratory-based real time system - FY 98
- Demonstrate operationally a human error prediction system as applied to the design of aircraft maintenance - FY 99

NASA SAMPLE PRODUCTS AND MILESTONES - FY 95-02+

Sub-Area	FY 95-97	FY 97-02	FY 02+
Human-Centered Automation	Complete field evaluation of concepts, technology and procedures for extended terminal area air traffic controller automation aids Human Automation Conference (NASA, FAA, DOD sponsored)	Provide Validated Guidelines for Robust Air Traffic Management Operations with Varying Levels of Automation and Varying Combinations of Data Link and Voice Air-Ground Communications Demonstrate Operational Procedures and Guidance/Displays for Safe, Low Altitude, Terminal Area Operations in Civil Rotorcraft	Demonstration of boredom and fatigue alertness monitor
Selection and Training		Validation of Guidelines and Standards in Flight for Certification of Pilots and Integrated Controls and Displays for Reduced Time and Cost for Pilot Training	
Human Performance Assessment	Complete Simulation of MIDAS to Analyze and Evaluate Proposed Cockpit Designs and Crew Procedures for Civil Tiltrotor Terminal Area Operations		
Information Management and Display	Flight Evaluation of Integrated Controls and Technology	Demonstrate a Real-Time System Landing an Aircraft Without Forward Visual Aiding Through Enhanced/Synthetic Displays Demonstrate Under Operational Conditions an Enhanced/Synthetic Vision System for Aircraft Operations	
Bioaeronautics			Demonstration of crew scheduling expert system

Appendix B3: FAA Implementation Plan

The FAA manages and operates the National Airspace System and, as such, is dedicated to contributing to a safe and efficient global aviation system. Human factors research efforts within the organization support both acquisition and operations requirements. In acquisition, system specific research needs are addressed by integrated product teams (IPT). Additionally, a core discipline research program exists to address basic and applied research needs which cut across IPTs. The core program also provides human factors and aviation medicine support for operations activities in regulation and certification. The sample products and milestones articulated in this appendix represent the focus and output of the core program being executed by the agency.

A more detailed description of the program can be found in the FAA Research, Engineering, and Development (R,E,&D) Plan which is published annually and provided to the Congress in accordance with the Aviation Safety Research Act of 1988 (Public Law 100-591).

FAA SAMPLE PRODUCTS AND MILESTONES - FY 95-02+

Sub-Area	FY 95-97	FY 97-02	FY 02+
Human-Centered Automation	Safety and Automation Level Relationships for Cockpit and Air Traffic	Flight Data Sensor Integration Report	Human Centered Design Guidelines for Future Flight deck and Air Traffic Control Automated Systems
Selection and Training	Advanced Qualification Program Model for Air Taxi and Commercial (Part 135) Operators Revised AC120-54 on Advanced Qualification Program Validated Aircraft Certification Service Supervisor Selection Program Validated Air Traffic Service Selection Criteria	Crew Decision Training Guidelines Refined Model Advanced Qualification Program for Air Carriers, Air Taxi, and Commercial (Part 121 and 135) Operators Recommendations for Supervisor/Managerial Selection System Model Management Selection Criteria	Validated Executive Selection Validated Air Traffic Controller Advanced Systems Personnel Selection Tools
Human Performance Assessment	Initial Automated Performance Measurement System (APMS) Prototype Baseline Controller Performance Metrics for Tower, TRACON, and En Route	APMS Specifications for Airline Use Operational Error Prevention Guidelines	Methods of Assessing and Enhancing Human Performance in Future NAS Systems
Information Management and Display	Human Factors Design Guidelines for Digital Communications Electronic Chart Design Guidelines Initial Information, Display, and Procedure Criteria for Free Flight	Expert System for Aviation Safety Inspectors Performance Specifications for Operations Control Center Workstations	Human Factors Guidelines for Information Management in Next Generation NAS Systems
Bioaeronautics	Standards for Improved Aircraft Child Restraint	Guidelines for Dual Aisle Evacuation	Evacuation Models for Future Aircraft

U.S. Department
of Transportation

**Federal Aviation
Administration**

Memorandum

Subject:
Comments on the National Plan for Civil Aviation Human Factors

Date:

To: All Recipients

Reply to: FAA (AAR-100)
Attn: Mark Hofmann,
Ph.D.

800 Independence
Ave., SW

Washington, DC 20591

Comment Instructions:
Please note the page number and paragraph in the document that your comment references.